EFFICIENCY TEST OF A 40. HORSEPOWER HALLADAY MOTOR CAR

BY
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ARMOUR INSTITUTE OF TECHNOLOGY

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EFFICIENCY TEST OF A 40 HORSEPOWER HALLADAY MOTOR CAR

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A THESIS

PRESENTED BY

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LeRoy David Kiley

TO THE

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H. M. Raymond
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Dean of Coll. Studies.

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H. F. Gebhardt

EFFICIENCY TEST OF A FORTY HORSEPOWER HALLADAY MOTOR CAR

A T H E S I S

Presented

MAY 29 1912

By Harvey A. Bohlander

LeRoy D. Kiley

23489

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The construction and arrangement of the automobile chassis of today is governed by different ideas held by the designers, and the ideal structure if already found must prove itself, and if not, the future still holds in store a different adaptation of the elements constituting this piece of mechanism.

The Halladay chassis embodies the fundamental principles of design in vogue at the present time and it is the purpose of this test, if possible, to discover the salient features which may effect either favorably or unfavorably the efficacy of the combination, the better to point out the inefficiency or the efficiency, as the case may be.

Before proceeding with this test the utmost care must be observed in the smallest details, and these features of the work are outlined in following pages.

From previous experimental work it has been shown that gasoline engines possess a charac-

teristic power curve, the horsepower increasing with the number of revolutions per minute, up to a certain point, and then dropping off quite rapidly. In this test the engine horsepower followed the expected course, but the curve shows merely a flattening at the apparent maximum point and exhibits no tendency to fall. This may be attributed to the fact that higher speeds were possible under heavier loads than those carried. The highest speed shown in the curves is 1580, while among the miscellaneous runs, numbered twelve to eighteen inclusive, engine speeds reaching as high as 1740 R.P.M. were used, as indicated by run number 18.

The miscellaneous runs were not used in determining the points on the curve as the results showed a departure from the apparent average due to heavier loads on the water brake and really giving points on a second load curve, higher speeds for the plotting of the same not being obtainable under such loads. The strain on the entire chassis at high

speeds threatened possible accident and at least could not but destroy conditions favorable to normal operation of the car, and hence more of these high speed runs were not made though desirable.

It is clear that the efficiency of the engine is a function of horsepower and fuel consumption, hence that speed at which the greatest horsepower may be had for the least amount of fuel is the most efficient speed for the engine, and all other conditions relative to the normal operation of the car should be adapted to this speed. In a racing car, where efficiency is a function of speed alone, the car is designed to operate normally at that highest speed of the engine producing the greatest horsepower, or in other words, for the peak of the power curve.

The dropping off of the horsepower of the engine at high speeds is undoubtedly due to the limiting capacity of the inlet and exhaust passages, improper seating of the valves, the incomplete

combustion of the fuel, the time element representing an important feature of the operation.

Discussion of power brings up two more sources of the measurement thereof; namely, the traction effort and the water absorption brake. These two horsepowers are co-ordinate, the one represented by a continuous manifestation of the power, and the other absorbing the power. Each is dependent upon the traction of the back wheels on the belts and any difference between them is due to the slipping of the belts upon the water dynamometer pulleys. The horsepower of the engine and that of the latter two sources of measurement differs in the horsepower lost in the various elements contributing to the transmission of the same. This quantity is fairly constant for all conditions of operation and is due to friction of the parts. All of the runs being made on high gear and hence direct connection existing between the clutch and the drive

shaft to the rear axle very little power was lost in the transmission proper. The universal joint connecting the transmission shaft and the drive shaft, no doubt represented an appreciable friction loss. The fact that the bevel gear housing was quite warm evidenced a considerable loss at that point.

The fuel consumption is clearly disclosed by the curves, the pounds per horsepower hour decreasing from slow speeds to normal and then again increasing for higher speeds. The pounds of fuel per engine horsepower hour consumed appear to show good economy varying from about .6 to .7. However, due to the aforementioned transmission losses, the pounds of fuel per brake horsepower hour is rather high. The last mentioned ratio is the more vital to the performance of the car as a whole. It is clear, therefore, that a good design from the engine to the driving wheels is more essential than an inferior one driven by an engine of surplus power.

The disposition of the thermal value of the fuel may be summed up as follows:

Heat converted into work 11 to 21.6%

Heat given to cooling water 20 to 50%

Heat Lost in exhaust, incomplete combustion, radiation, etc. 35 to 67%

The average results of the thermal value of the fuel are -

Heat converted into work 16%

" given to cooling water 34%

" lost in exhaust, incomplete combustion, radiation etc. 50%

The apparatus used is in some respects adapted to afford the chassis a more favorable test than the road and in other respects less favorable. The Kenerson Transmission Dynamometer may or may not give true indications of the engine horsepower. This dynamometer was calibrated in a tortion machine, but it is believed that this does not approach the rigorous trial of a rapidly rotating shaft and it should be calibrated against a motor load.

The pulley over which the cable passed

supporting the weights used to measure the tractive efforts was not at such a height as to permit of a purely horizontal pull by the chassis. An adjustable pulley adapted to different heights would be an ideal substitution for the present element.

It is thought that the addition of a suitable weight, placed on the chassis frame, over the rear springs would insure less slip of the tires on the belts, effect more nearly a straight line drive, and better simulate road conditions.

As seen by the accompanying running log sheets nine observations were supposed to be taken simultaneously. As only two men were running the tests, a period of from two to three minutes was occupied in obtaining the readings, hence any apparently absurd result might be attributed to a change in conditions during the noting of the observations. The gasoline and cooling water were always weighed exactly on the minute.

In a number of the runs the speed of the

back wheels was taken to determine, if possible, a difference from that of the engine, to detect slipping of the clutch, but no such slipping was evident. In all theruns the cooling water was admitted at a temperature of about 46° F., the exit temperature depending on the quantity flowing. It is believed that it would be better to use entering water at as high a temperature as possible inasmuch as the cylinders and pistons if at different temperatures would expand unequally and cause an appreciable loss in power due to binding.

....

The chassis tested was a forty horse-power 1910 model Halladay, having a four cylinder 4-1/2 X 5" water cooled Rutenber motor, a multiple disc clutch, selective transmission three speeds forward and reverse, full floating rear axle, 36" X 3-1/2" tires all around, and a wheel base of 118-1/2 inches. A heavy wooden frame having four adjustable bearing posts supports two similar shafts paralled to one another with broad iron pulleys rigidly fastened on the shaft ends, extending beyond the bearings. The bearings in the posts supporting the shafts are of the roller type and friction is neglible. Two continuous 6" belts are trained over the pulleys on each side of the frame, the upper spans of the belts serving to support the back wheels of the car. Chains provided with turnbuckles and hooking under the rear axle housing afford suspension for the rear of the car from the ceiling, when so desired, as when the belts are removed.

These chains are merely slacked when run-

ning a test, thus insuring a safety device to prevent the car from breaking ahead too far. The front of the car was first supported by iron standards beneath the front axle, but it was soon seen that these prevented the car from moving forward and exerting a pull on the traction weight. Consequently short runways about three feet long and fourteen inches high were constructed and placed beneath the front wheels.

A clamp adapted to grip a steel cable and also fit in the channel section of the rear frame cross piece was constructed to afford means whereby a weight secured to the steel cable passed over a pulley might be lifted, due to the tractive forward impulse of the car. This so-called traction weight consisted of a frame supporting ten standard fifty pound weights which rested on a platform scale.

Mounted upon the rear shaft supporting the aforesaid belts and pulleys is an Alden Absorption water dynamometer, having a brake arm of 18.925 inches. A steel yoke was made and fastened

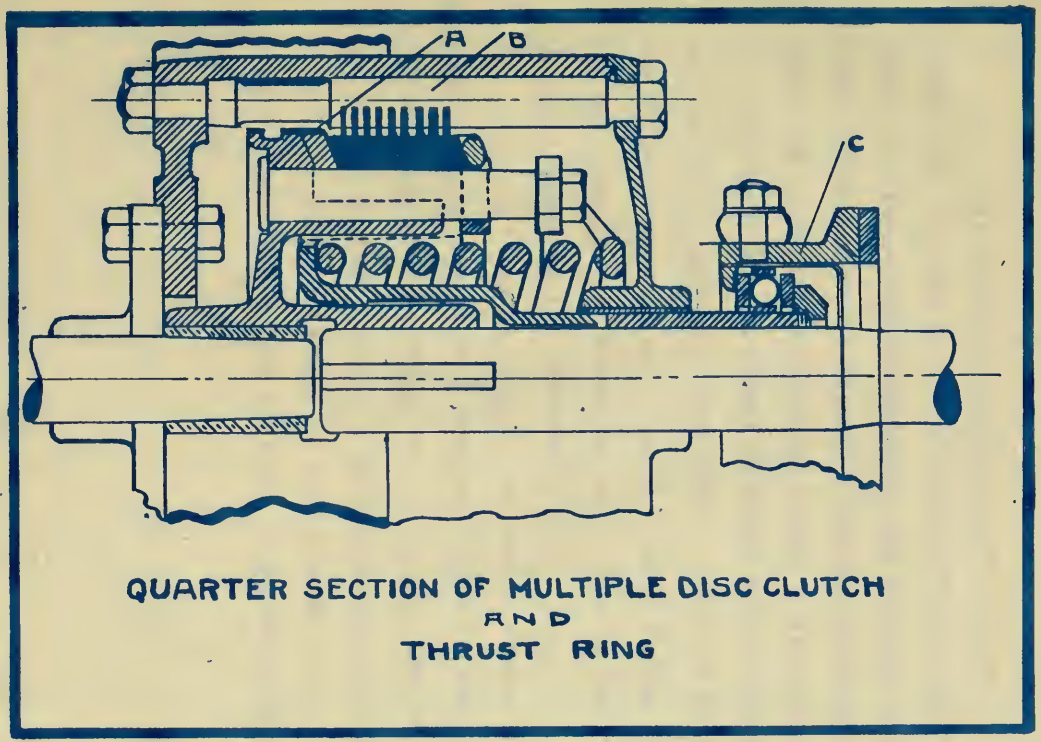
to the wooden frame in such a manner as to enclose the brake arm thereby limiting the movement thereof to about fifteen degrees. This is to prevent injury to any portion of the dynamometer, if it were free to rotate and strike some nearby object.

The cooling water for the engine and that for the dynamometer is piped directly to the respective elements requiring the same. Piping providing for the exit of the said water, to weighing tanks for the engine water and to the pump for the brake water, was installed by the observers. Brass thermometer cups were turned up and fitted in tees in the inlet and outlet water connections at the engine. Suitable means for conveniently using and weighing the gasoline were absent and so a platform was suspended from the ceiling by four half inch rods to a point about six inches above the dash of the car and the platform scale and tank placed thereon. Two platform scales are used, one reading to 50 pounds, for weighing the gasoline and accurate to two hundredths of a pound, and one to register the

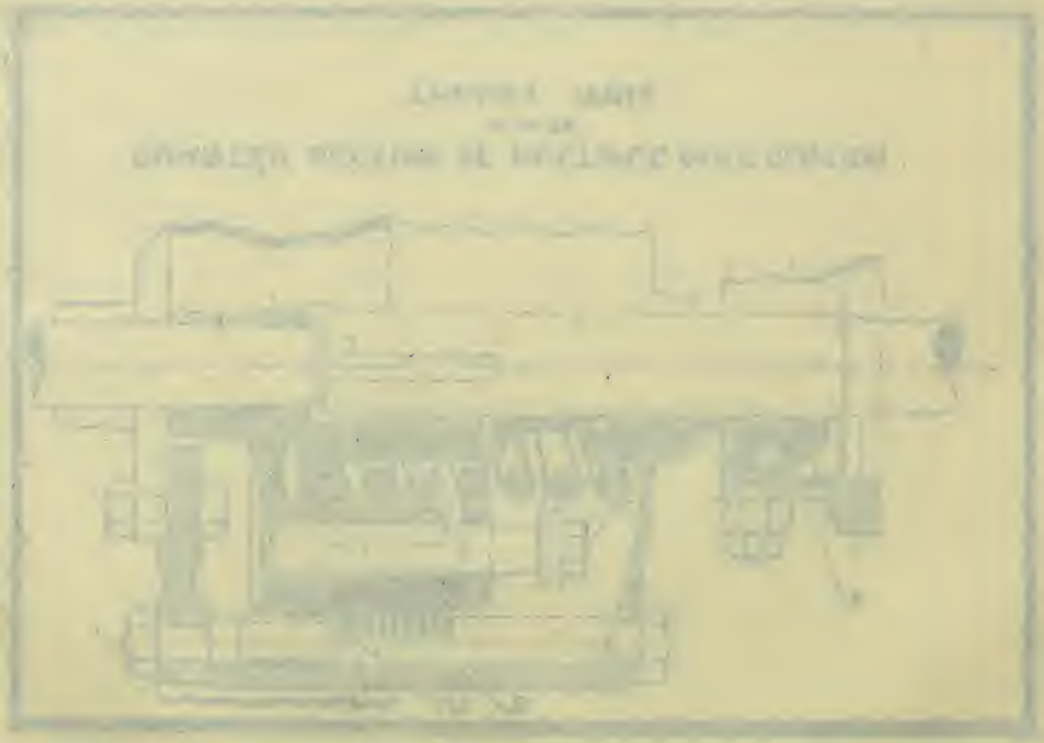
pressure of the water brake arm, the latter reading to 500 pounds and accurate to one tenth of a pound.

Mounted between the clutch and transmission is a Kenerson transmission dynamometer. The torque determining the power generated is transmitted to a gauge by means of oil pressure and the gauge is calibrated to read horsepower per hundred revolutions.

When the chassis was first turned over to the observers for work, the clutch refused to release and gear shifting was not feasible. It was first thought that the discs were sticking, but upon removal of the clutch, necessitating unbolting of the transmission casing, and the rear axle and tortion tube from the car frame, it was found that the base of the clutch was loose upon the shaft and the small retaining flange indicated by "A" in the sketch had ridden up on the recessed bolts "B" and thus jammed to the rotating cage caused the entire clutch mechanism to rotate, although the discs were free. An entire new clutch was therefore installed.



QUARTER SECTION OF MULTIPLE DISC CLUTCH
AND
THRUST RING



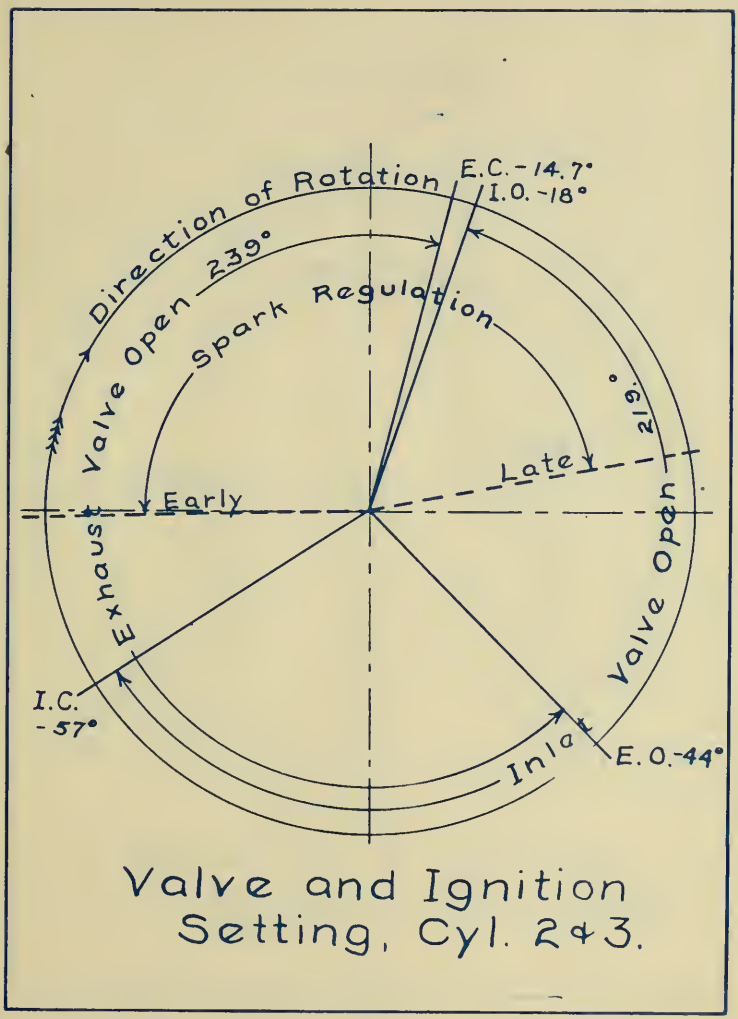
To prevent a repetition of such an occurrence, the end of the universal joint shaft between the clutch and transmission was recessed and a 9/16 inch steel ball inserted between the said shaft and the main transmission shaft. This prevented any end motion due to thrust produced when disengaging the clutch with the foot pedal. The base of the clutch now having no opportunity to move along, the end play having been dispensed with, has no opportunity to bind on the recessed bolts.

It may be seen in the sketch of the clutch that a thrust ball bearing ring C is used to transmit the pressure from the foot pedal against the clutch spring. Due to a defective ball continuous use of the chassis during the test proved to be entirely disastrous to the ring and a new one must be put in place.

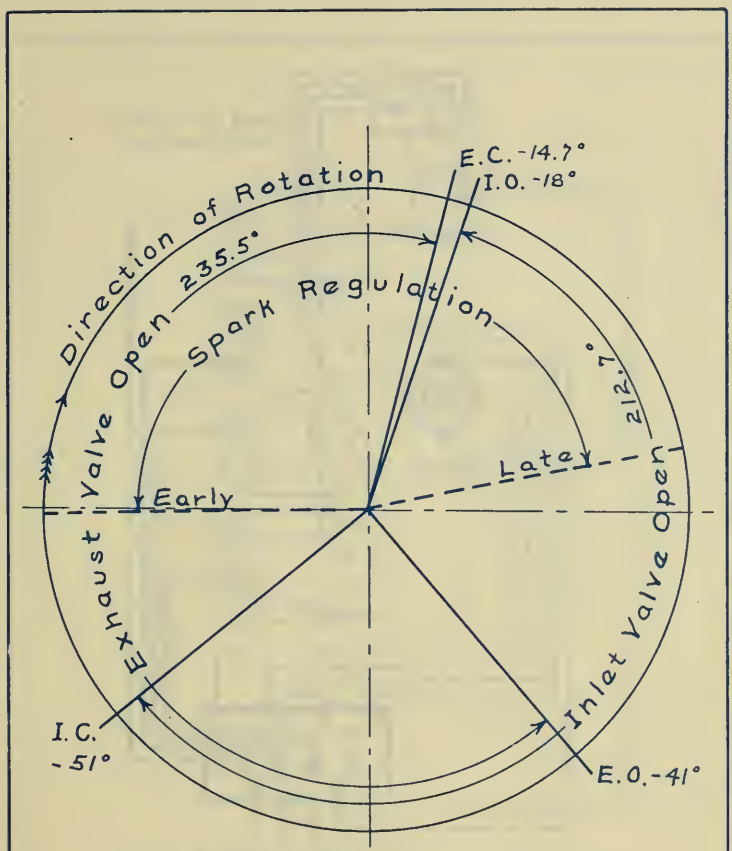
Before the engine was actually run a certain amount of preliminary data was essential. This included the timing of the battery spark, the timing of the valves, determination of the gear ratios, measurement of the brake arm and tare weight, and also the gross traction weight.

By rotating the engine slowly by hand the firing order was found to be 1-3-4-2. The circumference of the flywheel is fifty-five inches hence one inch is equal to 6.55 degrees. For maximum advance of the spark lever the cylinders were fired 90 degrees before dead center, and for maximum retard the firing occurred 84 degrees after dead center.

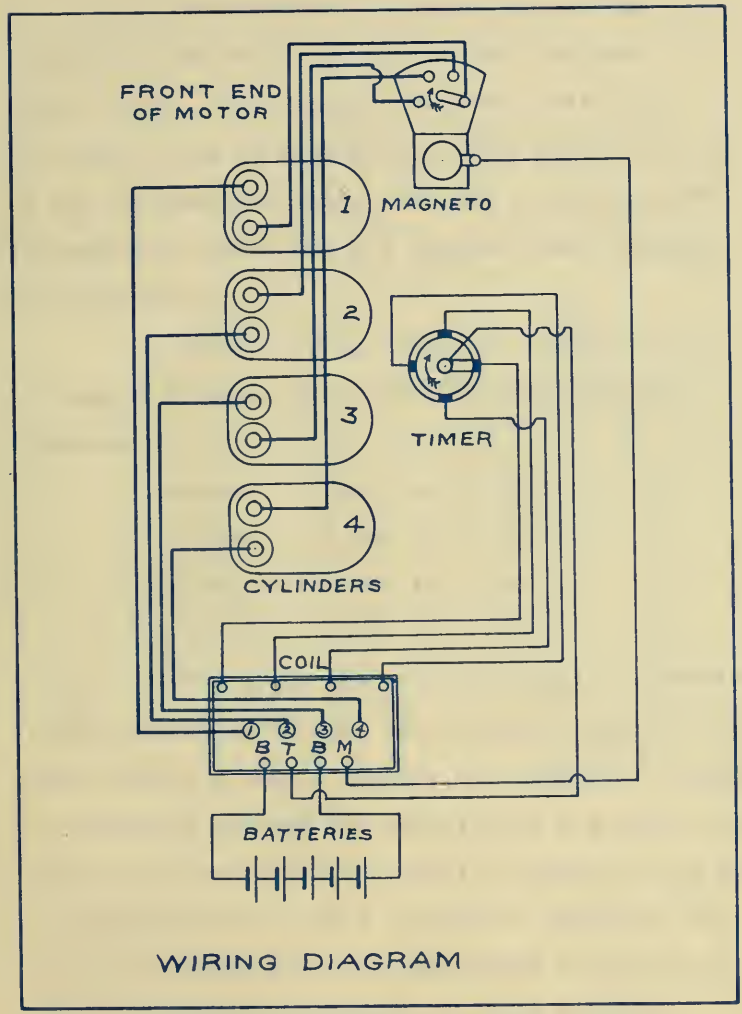
The following conventions were used in marking the flywheel for the opening and closing of the inlet and exhaust valves. All inlet valve occurrences denoted by one center punch, all exhaust valve occurences denoted by two center punches, all openings of values indicated by a capital "O", all closure of valves indicated by no mark whatever. The timing of the valves is more clearly disclosed by the valve diagrams themselves accompanying the thesis.



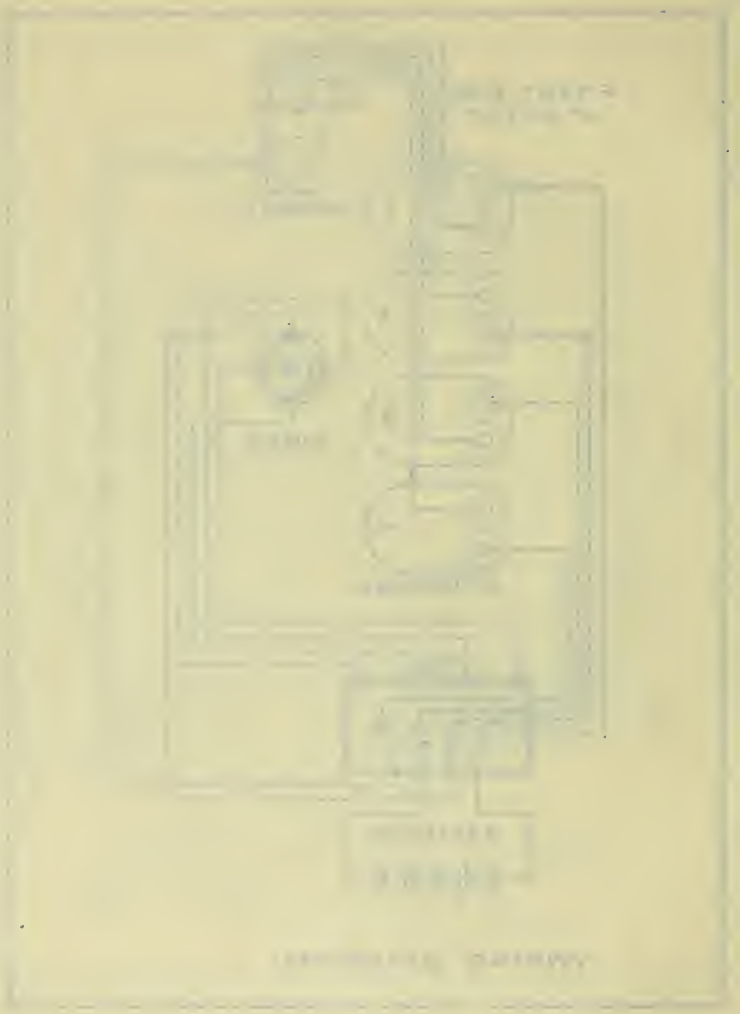
Valve and Ignition Setting, Cyl. 2 & 3.



Valve and Ignition Setting, Cyl. 1 & 4.



WIRING DIAGRAM



To determine the gear ratios the engine was turned slowly by hand and one rear wheel locked. This caused the other rear wheel to rotate twice as fast as when both were free, due to the differential gears, and the revolutions of the said free wheel and the flywheel were counted simultaneously.

The following ratios of the R.P.M. of the engine to those of the rear wheels were thus determined -

Reverse	13.33	to	1.00
Low gear	11.45	to	1.00
Second gear	5.83	to	1.00
High gear	3.50	to	1.00

The brake arm was originally constructed of such length as to make the constant in the horsepower formula a simple number. For aesthetic reasons the observers changed the position of the arm on the dynamometer drum which changed the length of the arm by .003 inches which is a negligible quantity. The length of the brake arm is now 18.925 inches which causes the constant in the horsepower formula

F and N being the only variables, to reduce to .0003.

$$\text{Thus } H.P. = \frac{2\pi rNF}{33000} = .0003\,NF$$

The tare water brake weight was found by reading the weight on the scale when the shaft was rotated uniformly by hand in one direction and subtracting this quantity from the weight registered by the scale when the shaft was rotated similarly in the opposite direction or toward the direction of the steel resting point on the brake arm. This difference or the tare weight was found to be 10.3 pounds.

In order to secure a tentative figure for the traction weight it was assumed that 25 horsepower would be a maximum value for the tractive effort of the rear wheels. $H.P. = \frac{2\pi rNF}{33000}$

$$F = \frac{25(33000)}{2(3.14)1.5(87.5)} = 600 \text{ lbs.}$$

By the foregoing calculations the traction weight comes out 600 pounds which was about 35 per cent more than required as shown by the tests.

A heavy reinforcing tension member was pin connected through the traction pulley and bolted to the rear member of the wooden frame to reduce side lash and possible accident the lone supporting previously thought sufficient.

The battery ignition for the engine was supplied by either one of two sets of storage cells, two cells in a set. In starting up a run one set was switched to the engine and the other put on charge, and when one set became weak the other two were interchanged. The fact that the chassis was higher than ordinary from the floor made cranking difficult and so the cylinders were always primed first to insure instant starting. The motor started easiest with the throttle half open and the spark advanced one third from the lowest point on the quadrant.

One observer took his place on the driving seat and the other manipulated the water valves on the dynamometer. The desired gear having been thrown in, and the water having been siphoned from the dynamometer to insure no load, the clutch was let gently into engagement. The man at the dynamometer adjusted the water pressure to give the desired load and the man at the wheel regulated the throttle to obtain the desired speed. All runs were made on the magneto with the spark ranging from three quarters to the limit of the quadrant.

The rate of flow of the cooling water was next adjusted by the inlet valves for that purpose, the radiator and fan being dispensed with. About five minutes running under the conditions imposed for that particular run were allowed previous to noting observations, in order that the running conditions should become fairly constant. The two observers with watches timed alike began operations at a given signal from one. This consisted in closing the outlet valve of the cooling water weighing tank and weighing the gasoline. One observer then read the speed of the engine and the water dynamometer while the other read the temperatures, loads, and weights. The length of the runs varied from five to twenty minutes; the high speed runs proving dangerous accounts for the shorter time runs.

The reading of the Kenerson dynamometer at high speeds was very difficult as it was impossible to bring the gauge needle to rest, the amplitude of vibration extending in some cases one whole division as from 2.0 to 3.0

The density of the gasoline used was determined in degrees Baume' by means of a corrective hydrometer. The heat valve of the fuel or number of B.T.U. per pound of gasoline was determined from the formula

$$B.T.U. = 18650 + 40 \text{ (Baume' } - 10)$$

$$\therefore B.T.U = 18650 + 40 \text{ (} 62.2 - 10)$$

$$= 20738 \text{ per pound}$$

Calibration of the Kenerson Dynamometer.

H.P. from dynamometer equals the reading times revolutions divided by 100

Thus $HP = R \times N \div 100$

The horsepower from the formula is

$$H.P. = \frac{2 \pi r N F}{33000}$$

$$\therefore \frac{R N}{100} = \frac{2 \pi r N F}{33000}$$

Let R equal one, then

$$33000 N = 100 \times 2 \pi r N F$$

$$\therefore r F = \frac{33000 N}{2 \pi N \times 100}$$

$$\therefore r F = 52.55 \text{ ft. lbs.}$$

$$\therefore \text{Reading 1} = 52.55 \text{ ft. lbs.}$$

Following is a table of figures found in the calibration of the Kenerson dynamometer in the tortion machine

Load in foot pounds	Reading	Load / 52.55 --corrected reading
0	.00	.00
25	.52	.476
50	1.01	.952
100	1.91	1.905
165	2.85	3.14
200	3.48	3.81
250	4.30	4.76
300	5.16	5.72
335	5.69	6.38
280	5.43	5.33
250	5.18	4.30
200	4.51	3.81
150	3.39	2.86
100	2.25	1.905
50	.92	.952
25	.50	.476
0	.00	.00

These results have been represented in the calibration curve accompanying the thesis.

Corrected Dynamometer Reading
Actual Dynamometer Reading
Mean
Calibration Curve
for
Kenerson
Dynamometer
0
1
2
3
4
5
DEPARTMENT OF MECHANICAL ENGINEERING
RENSSELAER POLYTECHNIC INSTITUTE
TROY, N.Y.

The gross traction weight on the scales was 520 pounds in runs 1, 2, and 3, and 540 pounds in all others. Since the pull of the car showed the difference, between the gross weight and the traction, on the scale beam, the scale reading had to be subtracted from the gross weight to obtain the pull.

The horsepower represented by the traction is found as follows:

$$H.P. = \frac{2 \pi r N.F}{33000}$$

Where r is the radius in feet of the rear wheels

N is the R.P.M.

F is the tractive effort in pounds.

The procedure of operations applies to runs made on low gear or second speed, but reverse cannot be used unless a lever is mounted over the brake arm to obtain a down thrust at its opposite end on the scale platform.

The accompanying log forms and summary of calculations together with the curves clearly exemplify the description of the thesis.

DATE April 27, 1912 GROSS TRACTION WT. 520 #

RUN 1 TARE WATER BRAKE WT. 10.3#

GEAR HIGH DENSITY OF GASOLINE 62.2

R. P. M.		LOADS			TEMPERATURE		WEIGHTS		TIME
ENGINE	WATER BRAKE	WATER BRAKE	TRACTION DIFFERENCE	TRANSMISSION DYNAMO-METER	INLET COOLING WATER	OUTLET COOLING WATER	GASOLINE	COOLING WATER	HOURS & MINUTES
613	240	101.5	355	1.95	47	83	29.75	557	10.53
617	242	103.0	360	1.95	46	83	29.0		10.58
616	242	102.0	360	1.95	47	83	28.39		11.03
620	247	102.0	360	1.95	48	83	27.78		11.08
616	242	104.0	360	1.95	48	83	27.0	1138	11.13
AVERAGES									
616.5	242.6	102.5	359	1.95	47.2	83.0	2.75	581	0.20

DATE _____

RUN

GEAR HIGH

R.P.M.		LOADS		TEMPERATURE		WEIGHTS		TIME
ENGINE	WATER BRAKE	WATER BRAKE	TORQUE ARM					

DATE April 27, 1912 — GROSS TRACTION WT. 520#

RUN 2 — TARE WATER BRAKE WT. 10.3#

GEAR HIGH — DENSITY OF GASOLINE 62.2

R. P. M.		LOADS			TEMPERATURE		WEIGHTS		TIME
ENGINE	WATER BRAKE	WATER BRAKE	TRACTION DIFFERENCE	TRANSMISSION DYNAMO-METER	INLET COOLING WATER	OUTLET COOLING WATER	GASOLINE	COOLING WATER	HOURS & MINUTES
752	305	112.1	355	2.0	46	84.0	24.90	556	11.35
737	292	112.1	355	2.1	46	84.0	23.90		11.40
720	290	112.1	355	2.1	45	84.2	23.10		11.45
720	290	112.1	355	2.1	46	84.3	22.20		11.50
732	291	112.1	355	2.1	45	84.0	21.39	1149	11.55
AVERAGES									
732.2	294.2	112.1	355	2.08	45.6	84.1	3.51	593	0.20

DATE _____ 1915

RUN _____ GEAR HIGH

	M.P.H.	LOAD	ENGINE	WATER	OIL

DATE April 27, 1912 — GROSS TRACTION WT. 540 #

RUN 3 — TARE WATER BRAKE WT. 10.3 #

GEAR HIGH — DENSITY OF GASOLINE 62.2

R. P. M.		LOADS			TEMPERATURE		WEIGHTS		TIME
ENGINE	WATER BRAKE	WATER BRAKE	TRACTION DIFFERENCE	TRANSMISSION DYNAMO-METER	INLET COOLING WATER	OUTLET COOLING WATER	GASOLINE	COOLING WATER	HOURS & MINUTES
880	345	138.0	340	2.6	46	93	19.0	556	12.10
860	320	138.5	340	2.7	46.8	93	17.8		12.15
870	340	139.0	340	2.5	46	93	16.79		12.20
830	340	139.0	340	2.5	46	93	15.69		12.25
810	340	139.5	340	2.6	46	93	14.60	1287	12.30
AVERAGES									
830	335	138.8	340	2.58	46.1	93	4.40	731	0.20

| | | |

DATE APRIL — 29 — 1912 GROSS TRACTION WT. 537 #

RUN 4 TARE WATER BRAKE WT. 10.3 #

GEAR HIGH DENSITY OF GASOLINE 62.2

R. P. M.		LOADS			TEMPERATURE		WEIGHTS		TIME
ENGINE	WATER BRAKE	WATER BRAKE	TRACTION DIFFERENCE	TRANSMISSION DYNAMO-METER	INLET COOLING WATER	OUTLET COOLING WATER	GASOLINE	COOLING WATER	HOURS & MINUTES
937	378	130	315	2.35	48	145.5	19.94	551	11—03
950	390	135	350	2.50	47	144.0	18.50		11-08
934	390	135	350	2.51	47	145.5	17.24		11-13
932	380	132	365	2.51	47	147.0	15.88		11-18
935	375	130	365	2.52	47	150.0	14.54	921	11-23
AVERAGES									
937.6	380.6	132.4	349	2.48	47.2	146.4	5.40	470	0-20

DATE _____ 1915 CROSS SECTION OF _____

RUN _____ TYPE OF CUT OR MAKE OF CAR _____

GEAR _____ HIGH _____ TRACK OR ROADBED _____

STATIONS	R. P. M.	SPEED	TIME	MOTOR	T.	REMARKS

DATE April 29, 1912 — GROSS TRACTION WT. 540 #

RUN 5 — TARE WATER BRAKE WT. 10.3 #

GEAR HIGH — DENSITY OF GASOLINE 62.2

R. P. M.		LOADS			TEMPERATURE		WEIGHTS		TIME
ENGINE	WATER BRAKE	WATER BRAKE	TRACTION DIFFERENCE	TRANSMISSION DYNAMO-METER	INLET COOLING WATER	OUTLET COOLING WATER	GASOLINE	COOLING WATER	HOURS & MINUTES
1050	415	133	345	2.55	47	154.5	11.66		11.43
1050	415	133	345	2.60	47	155.5			11.48
1050	415	133	345	2.65	47	156.5	8.81		11.53
AVERAGES									
1050	415	133	345	2.55	47	155.5	2.85		0.10

DATE _____ 19[illegible]

GEAR _____ HIGH

RUN _____

R.P.M.	SPEED	TORQUE	TEMPERATURE	MISC.	T.T.

DATE April—29—1912 GROSS TRACTION WT. 540#

RUN 6 TARE WATER BRAKE WT. 10.3#

GEAR HIGH DENSITY OF GASOLINE 62.2

R. P. M.		LOADS			TEMPERATURE		WEIGHTS		TIME
ENGINE	WATER BRAKE	WATER BRAKE	TRACTION DIFFERENCE	TRANSMISSION DYNAMO-METER	INLET COOLING WATER	OUTLET COOLING WATER	GASOLINE	COOLING WATER	HOURS & MINUTES
1050	415	126.0	395	2.48	47	141.0	25.92	531	3-15
1055	418	126.5	395	2.45	47	142.5	24.70		3-20
1060	416	122.1	411	2.45	47	143.0	23.44		3-25
1060	420	122.0	410	2.50	47	143.0	22.28		3-30
1070	422	125.0	410	2.50	47	144.0	21.00	960	3-35
AVERAGES									
1059	420.2	124.3	405	2.49	47	142.7	4.92	409	0-20

DATE 1912

RUN

GEAR HIGH

R.P.M.		LOADS		TEMPERATURES		WEIGHTS		TIME
AVERAGES								

DATE April 30, 1912 — GROSS TRACTION WT. 540 #

RUN 7 — TARE WATER BRAKE WT. 10.3 #

GEAR HIGH — DENSITY OF GASOLINE 62.2

R. P. M.		LOADS			TEMPERATURE		WEIGHTS		TIME
ENGINE	WATER BRAKE	WATER BRAKE	TRACTION DIFFERENCE	TRANSMISSION DYNAMO-METER	INLET COOLING WATER	OUTLET COOLING WATER	GASOLINE	COOLING WATER	HOURS & MINUTES
1080	460	126.6	400	2.45	45	107	23.14	555	2.27
1100	460	128.3	410	2.40	44	107	21.78		2.32
1125	468	124.0	408	2.50	45	108	20.42		2.37
1150	473	124.4	420	2.60	45	110	19.06		2.42
1150	470	124.0	417	2.60	45	110	17.66	1250	2.47
AVERAGES									
1123	464.2	124.6	411	2.51	44.8	108.4	5.48	695	0.20

DATE
RUN
GEAR NEON

R.P.M.		Loads		Temperature		Weights		Tire
AVERAGES								

DATE April 30 1912 — GROSS TRACTION WT. 540#

RUN 8 — TARE WATER BRAKE WT. 10.3#

GEAR HIGH — DENSITY OF GASOLINE 62.2

R. P. M.		Loads			Temperature		Weights		Time
Engine	Water Brake	Water Brake	Traction Difference	Transmission Dynamo-Meter	Inlet Cooling Water	Outlet Cooling Water	Gasoline	Cooling Water	Hours & Minutes
1210	500	120	400	2.50	44	110	13.36	555	3–44
1260	510	120	390	2.50	44	116	11.82		3-49
1275	513	120	380	2.55	44	115	10.30		3-54
1270	512	120	380	2.60	44	116	8.84	1055	3-59
AVERAGES									
1254	509	120	387	2.53	44	1142	4.52	500	0–15

| | | |

DATE April 30, 1912 — GROSS TRACTION WT. 540 #

RUN 9 — TARE WATER BRAKE WT. 10.3 #

GEAR HIGH — DENSITY OF GASOLINE 62.2

R. P. M.		LOADS			TEMPERATURE		WEIGHTS		TIME
ENGINE	WATER BRAKE	WATER BRAKE	TRACTION DIFFERENCE	TRANSMISSION DYNAMO-METER	INLET COOLING WATER	OUTLET COOLING WATER	GASOLINE	COOLING WATER	HOURS & MINUTES
1365	550	111.5	387	2.40	44	110	24.12	553	4.46
1365	550	108.0	395	2.55	45	110	22.55		4.51
1400	550	107.2	385	2.75	45	111	20.78	925	4.56
AVERAGES									
1376	550	108.9	389	2.57	44.7	110.3	3.34	372	0.10

DATE
RUN
GEAR HIGH

R.P.M.		LOADS		Temperature		Weights		Time
AVERAGES								

DATE April — 30 — 1912 GROSS TRACTION WT. 540#

RUN 10 TARE WATER BRAKE WT. 10.3#

GEAR HIGH DENSITY OF GASOLINE 62.2

R. P. M.		LOADS			TEMPERATURE		WEIGHTS		TIME
ENGINE	WATER BRAKE	WATER BRAKE	TRACTION DIFFERENCE	TRANSMISSION DYNAMO-METER	INLET COOLING WATER	OUTLET COOLING WATER	GASOLINE	COOLING WATER	HOURS & MINUTES
1480	630	103.8	400	2.30	44	99	17.82	553	8-04
1490	630	90.0	400	2.30	44	101	16.12	785	8-09
AVERAGES									
1485	630	96.9	400	2.30	44	100	1.70	232	0-05

OBSERVATIONS

| | | |

DATE APRIL-30-1912 GROSS TRACTION WT. 540#

RUN 11 TARE WATER BRAKE WT. 10.3#

GEAR HIGH DENSITY OF GASOLINE 62.2

R. P. M.		LOADS			TEMPERATURE		WEIGHTS		TIME
ENGINE	WATER BRAKE	WATER BRAKE	TRACTION DIFFERENCE	TRANSMISSION DYNAMO-METER	INLET COOLING WATER	OUTLET COOLING WATER	GASOLINE	COOLING WATER	HOURS & MINUTES
——	——	100	390	2.15	44	100	13.50	553	8-40
1540	660	90	388	2.20	44	102	11.58		8-45
1600	660	94.8	389	2.30	44	103	9.54	965	8-50
1600	660	—	—	—	—	—	—	—	—
AVERAGES									
1580	660	94.9	389	2.22	44	101.7	3.96	412	0-10

| | | |

DATE APRIL – 29 – 1912 GROSS TRACTION WT. 540#

RUN 12 TARE WATER BRAKE WT. 10.3#

GEAR HIGH DENSITY OF GASOLINE 62.2

R. P. M.		LOADS			TEMPERATURE		WEIGHTS		TIME
ENGINE	WATER BRAKE	WATER BRAKE	TRACTION DIFFERENCE	TRANSMISSION DYNAMO-METER	INLET COOLING WATER	OUTLET COOLING WATER	GASOLINE	COOLING WATER	HOURS & MINUTES
512	200	122.2	390	2.15	47	108	11.92	551	10-05
512	200	120.0	390	2.20	48	110	11.16	—	10-10
505	204	120.0	390	2.20	48	111	9.54	—	10-15
508	204	120.0	390	2.20	48	111	8.86	—	10-20
508	204	130.0	390	2.20	48	112	8.14	908	10-25
AVERAGES									
509	402.4	120.4	390	2.19	47.8	110.4	3.78	457	0-20

| | | |

DATE May 1, 1912 — GROSS TRACTION WT. 540 #

RUN 13 — TARE WATER BRAKE WT. 10.3 #

GEAR HIGH — DENSITY OF GASOLINE 62.2

R. P. M.		LOADS			TEMPERATURE		WEIGHTS		TIME
ENGINE	WATER BRAKE	WATER BRAKE	TRACTION DIFFERENCE	TRANSMISSION DYNAMO-METER	INLET COOLING WATER	OUTLET COOLING WATER	GASOLINE	COOLING WATER	HOURS & MINUTES
625	270	220	205	3.3	47	128	20.50	552	1.50
625	250	220	205	3.3	47	126	19.34		1.55
640	250	220	205	3.35	47	124	17.40	725	1.59
AVERAGES									
630	257	220	205	3.32	47	126	3.10	1.63	0.09

DATE _____ 1912

RUN

GEAR HIGH

R. P. M.		LOADS					
AVERAGES							

DATE May 1, 1912 — GROSS TRACTION WT. 540 #

RUN 14 — TARE WATER BRAKE WT. 10.3 #

GEAR HIGH — DENSITY OF GASOLINE 62.2

R. P. M.		Loads			Temperature		Weights		Time
Engine	Water Brake	Water Brake	Traction Difference	Transmission Dynamo-Meter	Inlet Cooling Water	Outlet Cooling Water	Gasoline	Cooling Water	Hours & Minutes
550	222	206	285	3.0	47	106	33.90	552	11.02
550	190	217	280	3.0	47	107	32.90		11.07
550	222	210	280	3.1	47	107	31.70		11.12
630	236	202	288	3.2	47	109	29.58	908	11.17
AVERAGES									
570	217.5	208.7	283.2	3.08	47	107.2	4.32	356	0.15

DATE _____ 1912

RUN

CLAIM

AVERAGES								

DATE April – 29 – 1912 GROSS TRACTION WT. 540#

RUN 15 TARE WATER BRAKE WT. 10.3#

GEAR HIGH DENSITY OF GASOLINE 62.2

R. P. M.		Loads			Temperature		Weights		Time
Engine	Water Brake	Water Brake	Traction Difference	Transmission Dynamo-Meter	Inlet Cooling Water	Outlet Cooling Water	Gasoline	Cooling Water	Hours & Minutes
700	280	171.5	350	3.10	47	130.5	15.4	552	4-31
700	270	173.8	350	3.05	47	133.0	14.12	—	4-36
700	280	173.9	350	3.15	47	133.0	13.0	—	4-41
700	284	173.9	350	3.20	47	133.5	11.90	—	4-46
715	—	173.9	350	3.10	47	133.0	10.76	945	4-51
AVERAGES									
703	278.5	173.6	350	3.12	47	132.6	4.64	393	0-20

| | | |

DATE May 1, 1912 — GROSS TRACTION WT. 540 #

RUN 16 — TARE WATER BRAKE WT. 10.3 #

GEAR HIGH — DENSITY OF GASOLINE 62.2

R. P. M.		LOADS			TEMPERATURE		WEIGHTS		TIME
ENGINE	WATER BRAKE	WATER BRAKE	TRACTION DIFFERENCE	TRANSMISSION DYNAMO-METER	INLET COOLING WATER	OUTLET COOLING WATER	GASOLINE	COOLING WATER	HOURS & MINUTES
1050	445	154	330	2.75	46	133	17.24	552	2.08
1045	430	150	330	2.75	46	141	15.74		2.13
1075	450	145	330	2.80	46	143	14.14	755	2.18
AVERAGES									
1057	441	149.7	330	2.77	46	139.3	3.10	203	0.10

DATE April – 30 — 1912 GROSS TRACTION WT. 540#

RUN 17 TARE WATER BRAKE WT. 10.3#

GEAR HIGH DENSITY OF GASOLINE 62.2

R. P. M.		Loads			Temperature		Weights		Time
Engine	Water Brake	Water Brake	Traction Difference	Transmission Dynamo-Meter	Inlet Cooling Water	Outlet Cooling Water	Gasoline	Cooling Water	Hours & Minutes
1340	554	116.2	380	2.5	45	108	17.06	557	5–39
1400	556	110.0	395	2.6	45	110	15.46	—	5–44
1400	—	112	375	2.7	45	110	13.80	930	5–49
AVERAGES									
1380	555	112.7	380	2.6	45	109.3	3.26	373	0–10

OBSERVATIONS IN KENSINGTON GARDENS — 1915

Date	Max. Temp.	Min. Temp.	Rainfall	Sunshine	Remarks

DATE MAY-1 — 1912

RUN 18

GEAR HIGH

GROSS TRACTION WT. 540*

TARE WATER BRAKE WT. 10.3*

DENSITY OF GASOLINE 62.2

R. P. M.		LOADS			TEMPERATURE		WEIGHTS		TIME
ENGINE	WATER BRAKE	WATER BRAKE	TRACTION DIFFERENCE	TRANSMISSION DYNAMO-METER	INLET COOLING WATER	OUTLET COOLING WATER	GASOLINE	COOLING WATER	HOURS & MINUTES
1740	675	94.5	442	2.40	47	127	28.8	552	11-26
1740	685	94.2	442	2.40	47	132	26.68	—	11-31
1700	670	97.0	442	2.40	47	133	24.67	830	11-36
AVERAGES									
1727	677	95.2	442	2.40	47	130.6	4.13	278	0-10

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SUMMARY OF AVERAGE RUNS

HIGH GEAR

RUN	R.P.M.		LOADS				DYNAMOMETER READINGS		GAS	WATER	TEMP.		TIME
NO.	ENGINE	WATER BRAKE	WATER BRAKE	NET	TRAC. DIFF.	NET	ACTUAL	CORRECTED	POUNDS	POUNDS	INLET WATER	OUTLET WATER	MIN.
1	616	242	102.5	92.2	359	161	1.95	1.84	2.75	581	47.2	83.0	20
2	732	294	112.1	101.8	355	165	2.08	1.97	3.51	593	45.6	84.1	20
3	830	335	138.8	128.5	340	180	2.58	2.47	4.40	731	46.1	93.0	20
4	937	380	132.4	122.1	349	191	2.48	2.36	5.40	470	47.2	146.4	20
5	1050	415	133.0	122.7	345	195	2.55	2.43	2.85	No Weight	47.0	155.5	10
6	1059	420	124.3	114.0	405	135	2.49	2.38	4.92	409	47.0	142.7	20
7	1123	464	124.6	114.3	411	129	2.51	2.40	5.48	695	44.8	108.4	20
8	1254	509	120.0	109.7	387	153	2.53	2.42	4.52	500	44.0	114.2	15
9	1376	550	108.9	98.6	389	151	2.57	2.44	3.34	372	44.7	110.3	10
10	1485	630	96.9	86.6	400	140	2.30	2.18	1.70	232	44.0	100.0	5
11	1580	660	94.9	84.6	389	151	2.22	2.10	3.96	412	44.0	101.7	10

SEMINARY TO TABERNACLE

HIGH

Calculations of Average Runs
High Gear

RUN No.	Horse Power		Gasoline		Total B.T.U. per E.H.P.Hr.	Cooling-Wat.		WORK		Lost in Exh., Rad. & Inc. Com.	
	Engine	Water Brake	Lbs. per E.H.P.Hr.	Lbs. per B.H.P.Hr.		B.T.U.	%	B.T.U.	%	B.T.U.	%
1	11.35	6.70	0.727	1.23	15050	5500	36.6	2545	16.9	7005	46.5
2	14.45	8.97	0.752	1.21	15550	4740	30.4	"	16.3	8265	53.1
3	20.50	12.90	0.658	1.04	13600	5030	37.0	"	18.7	6025	44.3
4	22.10	13.90	0.737	1.17	15250	6320	41.4	"	16.7	6385	41.8
5	25.50	15.25	0.670	1.12	13900						
6	25.30	14.35	0.583	1.03	12100	5150	42.6	"	21.0	4405	36.4
7	26.95	15.90	0.610	1.04	12650	4150	32.8	"	20.1	5955	47.1
8	30.30	16.80	0.595	1.07	12320	4630	37.6	"	20.6	5145	41.7
9	33.55	16.30	0.596	1.22	12330	4370	35.4	"	20.6	5415	44.1
10	32.40	16.25	0.630	1.26	13000	4810	37.0	"	19.6	5645	43.3
11	33.20	16.75	0.736	1.46	15250	4220	27.7	"	16.7	8485	55.6

CALIFORNIA SNOW SURVEY DATA

HIGH CSCO

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SUMMARY OF AVERAGE RUNS

HIGH GEAR

RUN	R.P.M.		LOADS				DYNAMOMETER READINGS		GAS	WATER	TEMP		TIME
No.	ENGINE	WATER BRAKE	WATER BRAKE	NET	TRAC. DIFF.	NET	ACTUAL	CORRECTED	POUNDS	POUNDS	INLET WATER	OUTLET WATER	MIN.
MISCELLANEOUS RUNS													
12	509	202	120.4	110.1	390	150	2.19	2.07	3.78	457	47.8	110.4	20
13	630	257	220	209.7	205	335	3.32	3.19	3.10	163	47.0	126	9
14	570	217	208.7	198.4	283	257	3.08	2.96	4.32	356	47.0	107.2	15
15	703	278	173.6	163.3	350	190	3.12	3.00	4.64	393	47.0	132.6	20
16	1057	441	149.7	139.4	330	210	2.77	2.65	3.10	203	46.0	139.3	10
17	1380	555	112.7	102.4	380	160	2.60	2.49	3.26	373	45.0	109.3	10
18	1727	677	95.2	84.9	442	98	2.40	2.27	4.13	278	47.0	130.6	10

ELEMENTS OF MECHANICS

PART I

STATICS

CALCULATIONS OF AVERAGE RUNS

HIGH GEAR

RUN No.	HORSE POWER		GASOLINE		Total B.T.U. per E.H.P.Hr.	Cooling-Water.		Work		Lost in Exh. Rad.& Inc.Comb.	
	Engine	Water Brake	Lbs. per E.H.P.Hr.	Lbs. per B.H.P.Hr.		B.T.U.	%	B.T.U.	%	B.T.U.	%
MISCELLANEOUS RUNS											
12	10.54	6.67	1.075	1.70	22300	8130	36.5	2545	11.4	11625	52.0
13	20.10	16.13	1.030	1.28	21300	4370	20.5	"	11.9	14385	67.3
14	16.85	12.70	1.025	1.36	21200	5200	24.5	"	12.0	13455	63.4
15	21.10	13.63	0.696	1.08	14400	7220	50.2	"	17.7	4635	32.2
16	28.0	18.4	0.663	1.01	13700	4070	29.7	"	18.5	7085	51.7
17	34.4	17.05	0.568	1.09	11750	4180	35.6	"	21.6	5025	42.8
18	39.2	17.30	0.633	1.435	13100	3560	27.2	"	19.4	7000	53.3

| | | |

Engine Horse-Power
and
Gasoline
Consumption
Engine Horse Power
H.P.
Gas
Engine R.P.M.
Gasoline lbs/H.P.Hr.
0
200
400
600
800
1000
1200
1400
1600
1800
4
8
12
16
20
24
28
32
36
40

Brake Horse-Power
and
Gasoline
Consumption
Water-Brake Horse-Power
H.P.
Gas
Engine R.P.M.
Gasoline lbs./H.P. Hr.
0
200
400
600
800
1000
1200
1400
1600
1800
2
4
6
8
10
12
14
16
18
20
.25
.50
.75
1.00
1.25
1.50